of mathematics to calculate what these heights would be, if the earth's mass were absolutely unyielding. But the tides of long period are nearly free from the dynamical influences which render those of short period so intractable to calculation, and must in fact nearly follow the laws of the "equilibrium theory."

In 1867 it was not, however, even definitely known whether or not the tides of long period were of sensible height at any station. Although there has been a continual advance in the knowledge of tidal phenomena since that time, it is only within the last year that there is a sufficient accumulation of tidal observations, properly reduced by harmonic analysis, to make it possible to carry out Sir William Thomson's suggestion. The great advances in knowledge that have been recently made are principally due to the adoption of systematic tidal observation at a great number of stations by the Indian Government. The results of these observations are now being issued yearly by the Secretary of State for India in the form of tide-tables for the principal Indian ports. I have had the pleasure of carrying out the examination of the tidal records, and a detailed account of the work will appear at § 848 of the new edition of Thomson and Tait's "Natural Philosophy," now in the press.

The tides chosen for discussion were the lunar fortnightly declinational tide, and the lunar monthly elliptic tide. These tides must be free from the meteorological disturbances which make the heights of all the solar tides quite beyond prediction. The fortnightly and monthly tides consist in an alternate increase and diminution of the ellipticity of the elliptic spheroid of which the sea level (after elimination of the tidal oscillations of short period) forms a part. There are two parallels of latitude respectively north and south of the equator which are nodal lines, along which the water neither rises nor falls. When, in the northern hemisphere, the water is highest to the north of the nodal line of evanescent tide, it is lowest to the south of it, and *vice versâ*; and the like is true of the southern hemisphere. If the ocean covered the whole earth, the nodal lines would be in latitudes 35° 16′ N. and S. (at which latitudes $\frac{1}{3} - \sin^2 \textit{lat.}$ vanishes); but when the existence of land is taken into consideration, the nodal latitudes are shifted. Now according to Sir William Thomson's amended equilibrium theory of the tides, the shifting of the nodal latitudes depends on a certain definite integral, whose limits are determined by the distribution of land on the earth's surface.

For the purpose of examining the tidal records, it was therefore first necessary to evaluate this integral. Approximation is of course unavoidable, and for that end the irregular contours of the continents were replaced by meridians and parallels of latitude, and the integral evaluated by quadrature. This procedure will give results quite accurate enough for practical purposes. It appeared as the result of the quadrature that, if we assume the existence of a large Antarctic continent, the latitude of evanescent tide is 34° 40′, and if there is no such continent it is 34° 57′. Hence the displacement of the nodal latitudes due to the existence of land is very small.

This point having been settled, the mathematical expressions for the fortnightly and monthly tides are completely determinate, according to the equilibrium theory, with no yielding of the earth's mass.

If there is yielding of the earth, either with perfect or imperfect elasticity, and with frictional resistance to the motion of the water, the height of tide and the time of high water must depart from the laws assigned by the equilibrium theory. This conclusion may also be stated in another way, which is more convenient for practical purposes; for we may say that at any station there must actually be a tide with a height equal to some fraction of the full equilibrium height, and with high water exactly at the theoretical time, and a second tide, of exactly the same nature, with a height equal to some other fraction of the equilibrium height, but differing in the time of high water by a quarter-period from the theoretical time, viz. about three-and-a-half-days for the fortnightly, and a week for the monthly tide. These two tides may, according to geometrical analogy, be called perpendicular component tides. According to the theory of the composition of harmonic motions, the two components may be compounded into a single tide, with time of high water occurring within a half-period of the theoretical time; and this is the way in which the results of elastic yielding and frictional resistance were first stated above. Thus the actual tide at any station involves two unknown fractions, x and y, being the factors by which two components, each of the full theoretical height, are to be multiplied in order to give the two components in proper amount to represent the reality.

If the equilibrium theory is fulfilled without sensible elastic yielding of the earth, the first component has its full value, or x is equal to one, and the second component vanishes, or y is zero. If fluid friction exercises a sensible influence, y will have a sensible value; and if the solid earth yields tidally, x will be less than unity. The amount of elastic yielding, and hence the average modulus of elasticity of the whole earth may be computed from the value of x. After rejecting the observations made at certain stations for sufficient reasons, I obtained from the Tidal Reports of the British Association and from the Indian Tide Tables, the results of thirty-three years of observation, made at fourteen different ports in England, France, and India.

These results, when properly reduced, gave thirty-three equations for the x and thirty-three for the y of the fortnightly tide, and similarly thirty-three for the x and thirty-three for the y of the monthly tide; in all 132 equations for four unknowns.

The x and y of the two classes of tide were in the first instance regarded as distinct, but the manner in which they arise shows that it is legitimate to regard them as identical, and thus we have sixty-six equations for x and sixty-six for y.

The equations were then reduced by the methods of least squares, with the following results:—

For the fortnightly tide—

$$x = \cdot 675 \pm \cdot 056, \; y = \cdot 020 \pm \cdot 055.$$

And for the monthly tide—

$$x = \cdot 680 \pm \cdot 258, \; y = \cdot 090 \pm \cdot 218.$$

The numbers given with alternative signs are the probable errors.

The very close agreement between the x and y for the two tides is probably somewhat due to chance.

The smallness of the two y's is satisfactory; for, as above stated, if the equilibrium theory were true, they should vanish. Moreover, the signs are in agreement with what they should be, if friction is a sensible cause of tidal retardation. But considering the magnitude of the probable errors, it is of course more likely that the non-evanescence of the y's is due to errors of observation or to the method of reduction.

I have already submitted to the British Association at this meeting a paper on a misprint, discovered by Prof. Adams, in the tidal report for 1872. This report forms the basis of the method of harmonic analysis which has been employed in the reduction of the tidal observations, and it appears that the erroneous formula has been systematically used. The large probable error in the value of the monthly tide may most probably be reduced by a correct treatment of the original tidal records.

It has been already remarked that it is legitimate to combine all the observations together, for both sorts of tide, and thus to obtain a single x and y from sixty-six years of observation. Carrying out this idea, I find:

$$x = \cdot 676 \pm \cdot 076, \; y = \cdot 029 \pm \cdot 065.$$

These results really seem to present evidence of a tidal yielding of the earth's mass, and the value of the x is such as to show that the effective rigidity of the whole earth is about equal to that of steel.

But this result is open to some doubt for the following reason:—

Taking only the Indian results (forty-eight years in all), which are much more consistent than the English ones, I find

$$x = \cdot 931 \pm \cdot 056, \; y = \cdot 155 \pm \cdot 068.$$

We thus see that the more consistent observations seem to bring out the tides more nearly to their theoretical equilibrium values with no elastic yielding of the solid.

It is to be observed however that the Indian results being confined within a narrow range of latitude give (especially when we consider the absence of minute accuracy in my evaluation of the definite integral) a less searching test for the elastic yielding than a combination of results from all latitudes.

On the whole we may fairly conclude that, whilst there is some evidence of a tidal yielding of the earth's mass, that yielding is certainly small, and that the effective rigidity is at least as great as that of steel.

SCIENTIFIC SERIALS

The Journal of Physiology, vol. iii. Nos. 5 and 6, August, 1882, with Supplement number. No. 11 contains:—Optical illusions of motion, by H. P. Bowditch and G. S. Hall.—On

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reflex movements of the frog under the influence of strychnia, by G. L. Walton.—A contribution to our knowledge of the action of certain drugs upon bodily temperature, by H. C. Wood and E. T. Reichert.—Influence of Peptones and certain inorganic salts on the diastatic action of saliva, by R. H. Chittenden and J. S. Ely.—On cerebral localisation, by S. Exner.—The physiological action of methylkyanethine, by G. L. Walton.—On the influence of variations of intra-cardiac pressure upon the inhibitory action of the vagus nerve, by H. Sewell and F. Donaldson.—Preliminary observations on the innervation of the heart of the tortoise, by W. H. Gaskell.—Concerning the influence exerted by each of the constituents of the blood on the contraction of the ventricle, by S. Ringer (plate xix.).—The Supplement contains a list of works and papers on physiology published in 1881.

The American Naturalist for October, 1882, contains:—Sketch of the progress of North American Ichthyology in the year 1880-81, by W. N. Lockington.—On the methods of microscopical research in the zoological station at Naples, by C. O. Whitman.—On the homologies of the crustacean limb, by A. S. Packard, jun.—On the idols and idol worship of the Delaware Indians, by C. C. Abbott.

Journal de Physique, September.—Dynamo-electric machines with continuous currents, by M. Potier.—Influence of a metal on the nature of the surface of another metal placed at a very small distance, by M. Pellat.

SOCIETIES AND ACADEMIES

LONDON

Mineralogical Society, October 24.—Anniversary Meeting. W. H. Huddleston, F.G.S., president, in the chair.—Nine new Members were elected.—The officers and Council were elected for the ensuing year, the only changes being the election of Messrs. T. D. Gibb, T. M. Hall, Jas. I'Anson, and H. M. Plattnault, on the Council in place of Dr. Aitken, Professors Crum Brown and Hughes, and Mr. Louis, who retired *in rotation*.—It was resolved to hold the meetings of the Society at fixed dates for the ensuing year, viz., on December 13, 1882, February 15, May 15, and October 23 (Anniversary), the meeting for May to be held in Scotland.—The Report of the Council was read and adopted.

PARIS

Academy of Sciences, October 25.—M. Blanchard in the chair.—Herr Wiedemann presented the first volume of a new work by him, "Die Lehre von der Electricität."—On the effect of a stroke of an inclined cue on a billiard ball, by M. Résal.—Separation of gallium (continued), by M. Lecoq de Boisbaudran.—Contribution to the study of typhoid fever in Paris; the present epidemic, from September 22 to October 19, 1882, by M. de Pietra Santa. There have been 2225 deaths this year (up to the latter date), more than during the whole of last year 2130), (628 in the last four weeks). All the twenty arrondissements have been affected, and all the eighty quarters, except the four American and that of St. Fargeau in the west and Salpêtriere and Petit-Montrouge in the south. The seventh arrondissement has suffered most. M. Santa notices the unwholesome state of the houses.—On a bed of coal discovered in the province of Algiers, and on layers of white sand accompanying it, by M. Pinard. This is near Bou Saada. The coal is at least equivalent in illuminating power and yield of gas to the best French and English coal. The yield of coke varies between 62 and 66 per cent. The sand, which might be used for the finest glass, and is very abundant, is the product of disaggregation of immense banks of grit.—Results of modes of treatment adopted in 1881-82, in the Alpes-Maritimes, for destruction of phylloxera, by M. Laugier. More than 200 hectares have been treated with sulphide of carbon and sulphocarbonate of potassium, and the results are very satisfactory.—Observations of the great comet (Cruls) at the Observatory of Marseilles, by M. Borrelly.—Spectroscopic observations on the same comet, by MM. Thollon and Gouy. On October 9, the sodium lines seen on September 11, had disappeared; the four ordinary carbon bands were present; the nucleus gave a narrow continuous spectrum with many dark and bright lines. On the 16th the violet band was almost gone, and the continuous spectrum considerably weakened. The disappearance of the sodium lines and others observed by M. Lohse shows that under ordinary conditions the spectroscope cannot give us a complete analysis of cometary matter. If the temperature is sufficient to produce the emission spectrum of carbon compounds, it should be sufficient to produce that of sodium; but the facts are contrary. The authors incline to the electric theory of comets; in the case of a gaseous carburet traversed by the effluve from a Holtz machine, and holding fine metallic dust in suspension, the carbon bands appear, but not the metallic lines.—Relations between the residues of a function of an analytic point (x, y), which is reproduced, multiplied by a constant, when the point (x, y) describes a cycle, by M. Appell.—On the hyper-geometric functions of two variables, by M. Goursat.—Decomposition of a whole number N into its maximum *n*th powers, by M. Lemoine.—Lunar induction and its periods, by M. Quet.—On the automatic transmission and registration of messages of optic telegraphy, by M. de Brettes. A claim of priority.—On metallic thorium, by M. Nilson. He has reduced thorium by heating with sodium, the anhydrous double chloride of thorium and potassium, and adding to the mixture chloride of sodium; all in an iron crucible. The specific gravity of the pure metal is about 11·00; the substance, as prepared by Chydenius (density 7·657-7·795), was probably impure. For atomic volume, M. Nilson gets the value 21·1 (coinciding with the atomic volumes of zirconium (21·7), cerium (21·1), lanthanum (22·6), and didymium (21·5)).—Determination of the equivalent of thorium, by the same. The equivalent is equal to 58·10, if that of oxygen = 8 and that of sulphur = 16.—On benzylene orthotoluidine and methyl phenanthridine, by M. Etard.—On the reduction of nitrates in arable land, by MM. Deherain and Maquenne. An earth loses the property of reducing nitrates when it has been heated or submitted to chloroform vapours. Earth that has lost the property through heat, reduces anew when a little normal earth is added.—On the convulsing action of curare, by M. Couty. Curare is not only a paralysing poison, but also in the first place, slightly convulsing; nor merely a peripheric poison, but also, in certain measure, a poison of the nerve-centres.—On parasites of the blood in impaludism, by M. Laveran. He has observed them in 300 cases.—Isanemones of summer in the North Atlantic, by M. Brault. These curves of equal velocity of wind coincide with the isobars.—On turriform constructions of earth-worms in France, by M. Trouessart. He observed them in gardens in Angiers, and found they were produced by *Lumbricus Agricola*. Darwin knew only of this production by a *Perichaeta* naturalised at Nice, from the east. M. Gautrelat, in a note, affirmed that M. Le Bon's glyceroborate of soda is not a definite salt, but a mixture of monoborine (monoboric ether of glycerine), sub-borate of soda, and glycerine.—A map, by M. Durand Claye was presented, showing the increase of population in the department of the Seine, and adjacent parts of the department of Seine-et-Oise. The variations of growth are indicated by means of curves called *isoplèthes*.—Some documents from M. de Lesseps, relating to construction of the hospital of Panama, by the Canal Company, were presented.

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